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Journal of Plant Nutrition

Publication details, including instructions for authors and subscription information:

<http://www.informaworld.com/smpp/title~content=t713597277>

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Online publication date: 15 October 2010

To cite this Article Samarah, Nezar H. , Abu-Yahya, Anas E. and Grusak, Michael A.(2010) 'EFFECT OF MATURITY STAGES FOR WINTER- AND SPRING-SOWN CHICKPEA (*CICER ARIETINUM* L.) ON SEED MINERAL CONTENT', Journal of Plant Nutrition, 33: 14, 2094 — 2103

To link to this Article: DOI: 10.1080/01904167.2010.519083

URL: <http://dx.doi.org/10.1080/01904167.2010.519083>

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EFFECT OF MATURITY STAGES FOR WINTER- AND SPRING-SOWN CHICKPEA (*CICER ARIETINUM* L.) ON SEED MINERAL CONTENT

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□ Two-year field experiments were conducted to study the effect of two planting dates and seed maturity on mineral content of chickpea seeds. In 2003 and 2004, chickpea 'Jubiha-2' seeds were planted in late December (winter-sown) and early March (spring-sown). For both planting dates, pods were harvested at five maturity stages: 1) beginning of seed fill (BS), 2) full-size seed (FS), 3) greenish-yellow pod (GY), 4) yellow pod (Y), and 5) brown pod (B). The concentrations of nitrogen (N), potassium (K), phosphorus (P), magnesium (Mg), calcium (Ca), and zinc (Zn) on a dry weight basis significantly decreased as the seeds developed from the BS to the FS stage, then did not change significantly at the Y and B stages. Nutrient content (mg seed^{-1}) increased as the seed dry weight increased. Seeds from spring-sown plants had higher concentrations of N and manganese (Mn) than winter-sown plants. The maximum mineral content of chickpea was achieved at seed physiological maturity.

Keywords: chickpea, mineral nutrient, seed maturity, planting dates

INTRODUCTION

Chickpea is a major food legume in developing countries, since it provides an exchangeable source of proteins, carbohydrates, minerals, and vitamins, particularly for vegetarians and those who cannot afford meat. Carbohydrates and proteins constitute about 80% of the total seed dry weight of chickpea (Saxena and Singh, 1987). Total seed carbohydrate concentration varies from 53–71% while protein concentration varies from 17–24% (Gupta and Kapoor, 1980). Based on the amino acid composition, the proteins of chickpea seed have higher nutritive value than other legumes (Gupta and Kapoor, 1980). Also, chickpea seed contains an appreciable amount of

Received 31 December 2008; accepted 9 November 2009.

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non-protein nitrogen and total seed nitrogen, and provides a considerable amount of fat (4–10%) (Khanvilkar and Desai, 1981). Chickpea also is a rich source of minerals and vitamins and contains an appreciable amount of amino acids. According to Cowan et al. (1967) chickpea is a very good source of iron and a good source for providing calcium to low income people (Jambunathan and Singh, 1981). Chickpea is relatively rich in vitamins, especially vitamin C (ascorbic acid) (Chandra and Arora, 1968), and contains an appreciable amount of important amino acids such as lysine, that is limiting in cereals (Sandhu et al., 1974).

Seed mineral content may be affected by planting date and seed maturity. Delayed planting increased protein percentage in pea seeds (Siddique et al., 2002). In soybean, there was an increase in mineral accumulation during early seed filling period, but mineral accumulated at a slower rate during late seed filling (Sale and Campbell, 1980). There was a reduction in mineral concentration of soybean seeds during maturation (Sale and Campbell, 1980). This reduction in mineral concentration was most likely due to the increase in seed dry weight during maturation (Pascal and Crookstone, 1981). Murti (1975) found that carbohydrates and proteins of chickpea undergo noticeable biochemical changes during grain maturation. Winter-sowing increased seed yield of chickpea by 50 to 100% compared with spring-sowing date (Hawtin and Singh, 1984), but its effects on mineral content are sparse and need to be studied.

Therefore, the objective of this experiment was to study the effect of planting dates and seed maturity on mineral content of chickpea.

MATERIALS AND METHODS

Two field experiments were conducted at Maru Agricultural Station in Northern Jordan (located at 32° 37' latitude, 35° 53' E longitude, and 620 m altitude) under rainfed conditions during the 2003 and 2004 growing seasons. This location has a typical Mediterranean climate with 370 mm average annual rainfall. Soil type is silty clay with low level of organic matter (1.2%) and had a pH of 7.9. Chickpea variety 'Jubiha-2' obtained from the National Center for Agriculture Research and Extension (NCARE), Baq'a Jordan was used in both experiments. A fertilized soil of 20 kg nitrogen (N) and 50 kg phosphorus pentoxide (P_2O_5) ha^{-1} was tilled once prior to planting using a chisel plow. The main plot and sub-plot sizes were 500 and 125 m^2 , respectively, in both planting dates and growing seasons. Sowing was done by hand on two dates, on the 25th or 5th of December (winter-sowing date) and on the 5th or 10th of March (spring-sowing date) in 2003 and 2004 growing seasons, respectively. Pods were harvested at five developmental stages: 1) beginning of seed filling, 2) full-size seeds, 3) greenish yellow

TABLE 1 Sowing dates, harvest dates, and pod description for chickpea harvested at five maturity stages for plants grown in two planting dates (winter and spring) and two growing seasons (2003 and 2004)

Planting Date	Harvest Date		Maturity Stage	Pod Description
	2003	2004		
Winter	29 April	6 May	Beginning of seed	Pods were dark green; contained
Spring	6 May	12 May	filling (BS)	small, curled and greenish seeds.
Winter	10 May	17 May	Full-seed size (FS)	Pods were dark green, and seeds
Spring	17 May	26 May		filled the whole pod cavity.
Winter	21 May	24 May	Greenish yellow pod (GY)	Pods were yellowish green, contained
Spring	25 May	1 June		seeds that filled the whole pod cavity.
Winter	30 May	5 June	Yellow pod (Y)	Pods were yellow, filled with yellow
Spring	4 June	9 June		seeds.
Winter	6 June	12 June	Brown pod (B)	Pods were brown; contained dark
Spring	11 June	14 June		yellow seeds that filled two-thirds of the pod cavity.

pod, 4) yellow pod, and 5) brown pod. The description of these stages and the date of harvest are shown in Table 1. Seed dry weight of the harvested pods was determined for 20 seeds after oven-drying the seeds at 105°C for 72 h.

Seed mineral analysis was done for seeds harvested at all stages at NCARE laboratories. The dry weight of seeds was recorded after oven-drying at 70°C for 24 h. The samples were ground to a fine powder using a laboratory mill with 0.5 mm sieve, the milled product was mixed thoroughly, then samples of 1 g were ashed for 6 h at 550°C in a muffle furnace. The ash was dissolved in 5 mL of 2 M hydrochloric acid (HCl) for 20 minute, then 40 mL of 0.1 M HCl was added to the mixture before filtering using filter paper (Whatman no. 42). Phosphorus (P) was determined by taking 5 mL of the filtrate to a test tube, adding 1 mL ammonium molybdate-ammonium vanadate, and reading the absorbance at 410 nm with a spectrophotometer. Potassium (K) was measured by flame photometer. Calcium (Ca), Magnesium (Mg), Zinc (Zn), and Manganese (Mn) were measured by atomic absorption spectroscopy (Chapman and Pratt, 1961). Total nitrogen (Kjeldahl nitrogen) was determined according to Bremner and Mulvaney (1982) using an automatic titrator connected to a pH-meter.

The field experiments were arranged as a split-plot in a completely randomized block design with four replications. The sowing dates were assigned randomly to main plots and the harvesting dates were randomly assigned to subplots. Collected data were subjected to analysis of variance (ANOVA) using JMP 6 (SAS Institute, Cary, NC, USA). Probability of significance was used to indicate significant treatments and interactions effects. Means were separated according to student t test at 0.05 levels of probability.

RESULTS

Seed Dry Weight

The maturity stage and planting date had a significant effect on seed dry weight (Table 2). Because there was no significant interaction effect of the maturity stage \times planting date \times growing season on seed dry weight (Table 2), the mean for the maturity stage \times growing seasons and maturity stage \times planting date were shown in Table 3. Seed dry weight increased with seed maturity, reaching the maximum level at the Y and B stages in 2003 and 2004. Seeds harvested at the GY, Y, and B stages from spring-sown plants had higher seed dry weight than those harvested from winter-sown plants.

Seed Mineral Concentration

Maturity stage had a significant effect on the concentration of all mineral nutrients (Table 2). Because maturity stage \times growing season \times planting date interaction was not significant for N, K, Zn, or Mn (Table 2), the significant interaction of maturity stage \times growing season was shown (Table 4). In both growing seasons, the seed concentrations of N, K, Ca, and Zn decreased as the seeds developed from the BS to the FS stage. The seeds harvested at the GY, Y, and B stages were not different in N concentration. The concentration of N in seed from the Y stage in 2003 and the B stage in 2004 was lower than that of seeds collected from the FS stage in each year. The concentration of K decreased as the seeds developed from the FS stage to the GY stage, and then did not change significantly at the other stages except for the seeds

TABLE 2 P-value in analysis of variance (ANOVA) for seed dry weight and mineral concentration of chickpea seeds harvested at five maturity stages for plants grown in two planting dates (winter and spring) and two growing seasons (2003 and 2004)

Source	DF	P-Value						
		SDW	N	P	K	Mg	Zn	Mn
Year (Y)	1	ns†	ns	***‡	**	***	ns	ns
Block	3	ns	ns	ns	ns	ns	ns	ns
Error a	3							
Planting date (PD)	1	***	***	ns	ns	ns	ns	*
PD \times Y	1	ns	ns	***	ns	ns	ns	**
Error b	6							
Maturity stage (MS)	4	***	***	***	***	***	***	***
MS \times Y	4	**	***	***	***	*	**	**
MS \times PD	4	***	ns	ns	ns	ns	ns	ns
MS \times Y \times PD	4	ns	ns	*	ns	**	ns	ns
Error c	48							

† ns: not significantly different.

‡ *, **, *** Significantly different at probability of 0.05, 0.01, 0.001.

TABLE 3 Seed dry weight for chickpea seeds harvested at five maturity stages for plants grown in two planting dates (winter and spring) and two growing seasons (2003 and 2004)

Maturity Stage	Growing season seed dry weight (mg seed ⁻¹)	
	2003	2004
	Planting date seed dry weight (mg seed ⁻¹)	
	Winter	Spring
BS	11 e	11 e
FS	160 d	159 d
GY	272 b	252 c
Y	325 a	324 a
B	317 a	323 a

Means not followed by the same letters within columns and rows are significantly different at probability level of 0.05 according to Least Squares Means Differences Student's t-test.

harvested at the B stage in 2003. The concentration of Zn did not change significantly among the FS, GY, Y, and B stages except for the seeds harvested at the B stage in 2003. The concentration of Mn increased as seed developed from the BS to the FS stage, and then decreased as seed developed to the Y and B stages. In 2003, the concentration of Ca at the Y and B stages was lower than that at the GY stage, but the difference was not significant from the FS stage.

TABLE 4 Concentration of minerals in chickpea seeds harvested at five maturity stages for plants grown in two planting dates (winter and spring) and two growing seasons (2003 and 2004)

Maturity Stage	N		K		Ca	Zn		Mn	
	2003	2004	2003	2004	2003	2003	2004	2003	2004
	-----mg g ⁻¹ dw-----					-----μg g ⁻¹ dw-----			
BS	43.9a	36.5b	28.1a	14.0bc	2.2a	50.9a	46.9b	34.6de	40.2b
FS	33.3bc	33.0c	15.5b	11.2de	1.7bc	41.9cd	43.7bc	38.2bc	44.0a
GY	30.8cd	30.5cd	12.1de	8.6f	1.8b	40.2de	42.6cd	35.7cde	37.3bcd
Y	29.0d	30.7cd	12.5cd	7.8f	1.5c	43.1cd	41.8cd	33.8ef	30.6f
B	30.7cd	28.0d	11.2e	8.2f	1.5c	36.9e	43.3cd	31.0f	32.6ef
Planting date									
Winter		3.1b		1.3a	1.9a		43.8a	35.0b	34.9b
Spring		3.5a		1.3a	1.7a		42.4a	34.3b	38.9a

Means not followed by the same letters within columns and rows are significantly different at probability level of 0.05 according to Least Squares Means Differences Student's t-test.

TABLE 5 Concentration of minerals in chickpea seeds harvested at five maturity stages for plants grown in two planting dates (winter and spring) and two growing seasons (2003 and 2004)

Planting Date	Maturity Stage	P (mg g ⁻¹ dw)		Mg (mg g ⁻¹ dw)	
		2003	2004	2003	2004
Winter	BS	7.3a	4.8bc	1.6efg	2.3a
	FS	4.8bc	4.0ghi	1.6efg	1.8cde
	GY	4.4def	3.6jkl	1.5fgh	1.7def
	Y	4.3efg	3.3lm	1.5fgh	1.5fgh
	B	4.1fgh	3.9hij	1.4h	1.7def
Spring	BS	7.5a	4.9b	1.9bcd	2.1b
	FS	4.9bc	3.7ijk	1.4h	1.9bc
	GY	4.9bc	3.1mn	1.4gh	1.8cde
	Y	4.6cd	3.0n	1.5fgh	1.7def
	B	4.5de	3.5kl	1.5fgh	1.8cde

Means not followed by same letters within columns and rows are significantly different at probability level of 0.05 according to Least Squares Means Differences Student's t-test.

The interaction effect of maturity stage x planting date x growing season was significant for P and Mg (Tables 2 and 5). The concentration of P and Mg decreased as the seeds developed from the BS stage to the FS stage except for Mg in the winter season in 2003 (Table 5). The concentration of P at the GY stage was lower than at the FS stage in both planting dates and growing seasons except for the spring season in 2003. There was no significant difference in P concentration between the GY and Y stage. The concentration of P increased at the B stage compared with the Y stage in 2004, but not 2003. There was no difference in concentration of Mg in seeds from the GY, Y, and B stages.

Planting date had a significant effect on seed concentrations of N and Mn, but the effect was not significant on concentrations of P, K, Mg, and Zn (Table 2). Concentrations of N and Mn in seeds from spring-sown plants were significantly higher than seeds from winter-sown plants in both seasons (Table 4).

The growing season had a significant effect only on K, P, and Mg (Table 1). The concentrations of K (Table 4) and P (Table 5) in seeds from all stages were significantly higher in 2003 than in 2004 except for P concentration at the B stage from winter-sown plants in 2003 (Table 5). The concentration of Mg at the BS and B stages from winter-sown plants was higher in 2004 than in 2003. In the spring season, the concentration of Mg at the FS, GY, and B stages was higher in 2004 than in 2003.

Relationship of Seed Dry Weight with Seed Mineral Content

There was a significant positive linear relationship between seed dry weight and seed mineral content (mg seed⁻¹) for N, P, K, Ca, Mg, Zn, and

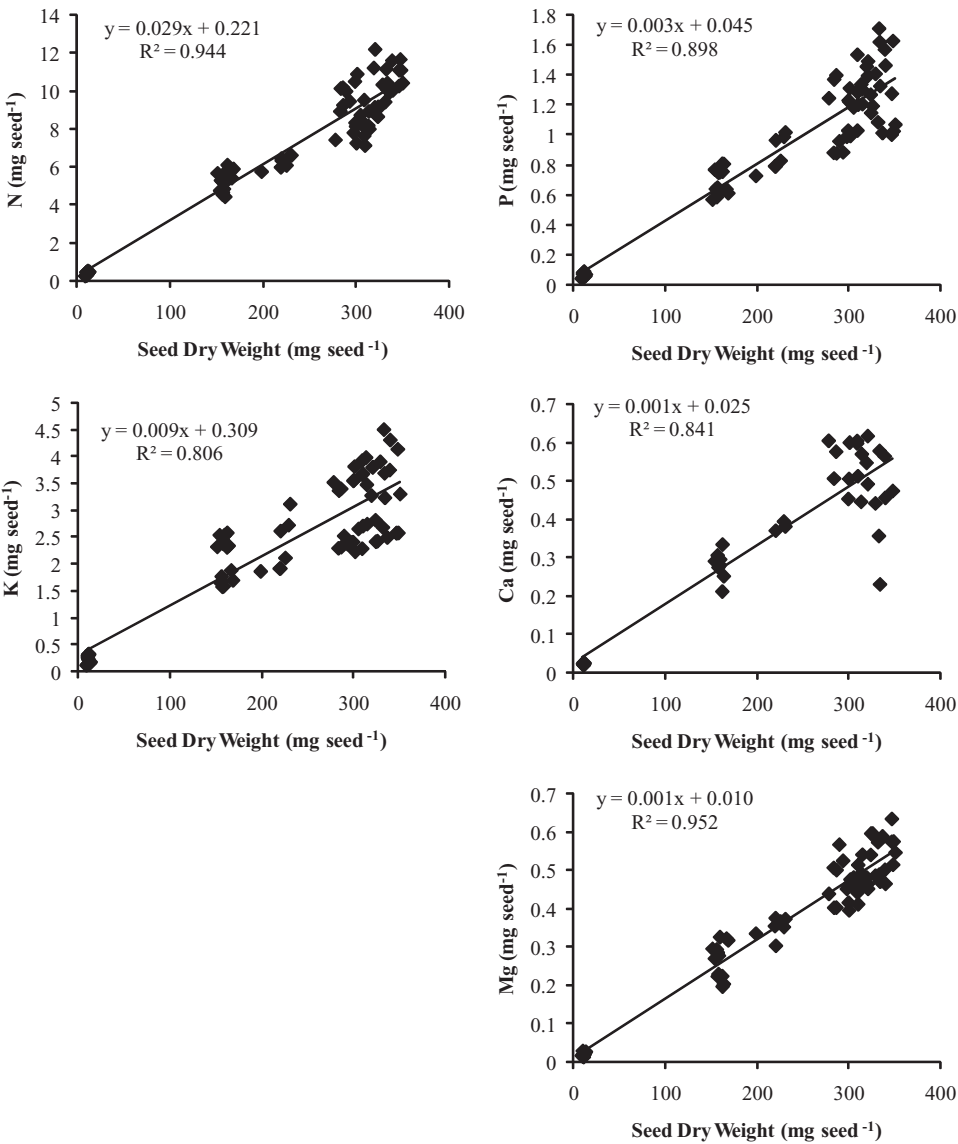


FIGURE 1 Relationship of seed dry weight with seed macro-nutrient content of chickpea.

Mn (Figures 1 and 2). As seed dry weight increased, the seed mineral content increased.

DISCUSSION

The concentrations of N, K, P, Mg, Ca, and Zn on a dry weight basis significantly decreased as the seeds developed from the BS to FS stage, then did not change significantly at the later maturity stages (Y and B stages). This

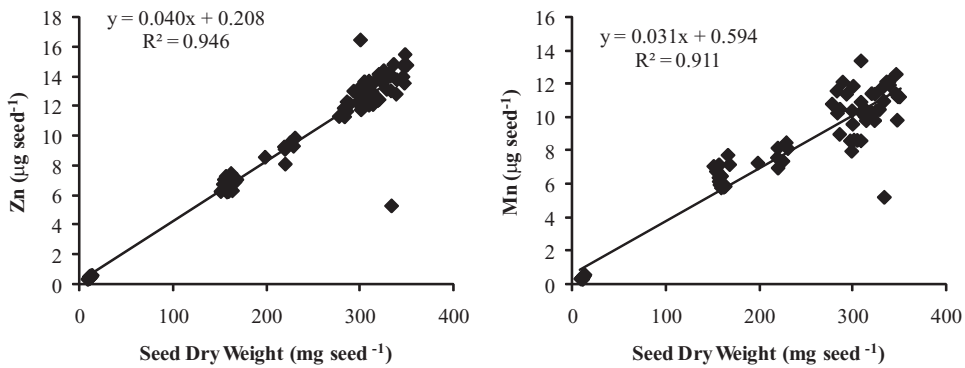


FIGURE 2 Relationship of seed dry weight with seed micro-nutrient content of chickpea.

reduction in nutrient concentrations with seed maturation was most likely due to the increase in seed dry weight accumulation with maturity (Pascal and Crookstone, 1981). In soybean seed, the nutrient concentrations were high during lag phase (the initial phase of seed development) of seed growth and the concentration decreased during the period of linear growth rate of seed (Sale and Campbell, 1980). In the present study, during the early stage of the lag phase of seed development, seeds had the greatest rate of dry weight accumulation (Table 3). The seeds reached the maximum dry weight when seeds were harvested at the Y stage of development, reaching the physiological maturity. This may explain the lower rate of the reduction in nutrient concentrations at the later stages of development in this study. In general, there was no significant decrease in nutrient concentrations when seeds developed from the Y to B stage. The results in the literature (Pascal and Crookstone, 1981; Sale and Campbell, 1980) and in the present study confirmed the fact that the nutrient concentrations on a dry weight basis decreased with seed maturity due to the dilution effect of the high rate of dry weight accumulation.

The effect of planting date on the concentrations of N and Mn might be due to the dry weight dilution or the pattern of translocation of nutrients to the developing seeds. The seeds harvested from spring-sown plants had higher concentrations of N in both seasons and Mn in 2004 than those harvested from winter-sown plants. The increase in the concentrations of N in spring-sown plants was inconsistent with Hymowitz et al. (1972), who reported that there was no effect of planting date on protein percentage in soybean seeds. In the present study, the increase in N concentration was consistent with Kane et al. (1997) in soybean and Siddique et al. (2002) in pea, who found that delayed planting increased protein percentage in seeds. Eck and Musick (1979) explained that the increase in N concentration in panicle of water-stressed sorghum was due to the reduction in dry matter accumulation under water stress, which resulted in less dilution of

accumulated N. Since the seeds harvested from spring-sown plants had higher seed dry weight than those seeds harvested at the same stage of maturity from winter-sown plants, the increase in N concentration in spring-sown seeds was unlikely due to seed growth dilution and could be due to the differences in allocation pattern of these nutrients to the developing seeds in spring-sown plants versus winter-sown plants. Since seed dry weight may affect nutrient concentrations during maturation due to growth dilution effect, the relationship between seed dry weight and seed mineral content (mg seed^{-1}) is shown in Figures 1 and 2. As seed dry weight increased, seed content of N, K, P, Ca, Mg, Mn, and Zn increased. Seed mineral content was significantly increased during soybean seed development and maturation (Sale and Campbell, 1980).

During the rapid expansion phase ($11 \text{ mg dry weight seed}^{-1}$ at the BS stage to 159 mg seed^{-1} at the FS stage), nutrient content had the most pronounced increase, but subsequent increases were progressively smaller (Figures 1 and 2). By the onset of seed physiological maturity ($325 \text{ mg dry weight seed}^{-1}$ at the Y stage), the seeds contained $>96\%$ of its final mineral nutrient content at maturity for N, P, K, Ca, Mg, Zn and Mn. At the onset of leaf senescence, about 80% of the final mineral nutrient content had been translocated to the seeds of soybean (Sale and Campbell, 1980).

Such information emphasized the importance of maturity stage and planting date on the concentration and accumulation of mineral nutrients, suggesting that the seeds attained the minimum concentration of mineral by the GY stage and the mineral concentration remains relatively stable thereafter. However, the accumulation of mineral in seed (mg seed^{-1}) increased as the seed dry weight increased. The maximum accumulation of mineral nutrient in seeds was achieved at the physiological maturity (the maximum accumulation of seed dry weight). The data suggest that nutrient translocation to seeds does not continue after seeds reach physiological maturity, indicating that mineral movement to seeds was directly coupled to assimilate movement.

ACKNOWLEDGMENTS

Thanks for Deanship of Research at Jordan University of Science and Technology for the financial support.

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